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HYDRO-ECOLOGICAL MODELING OF LOWER MISSISSIPPI RIVER

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INTRODUCTION

The Mississippi River (MR) is a major natural, economic, and industrial resource for the United States. Historically the MR was a major source of sediment, freshwater, and nutrients to virtually the entire coast of Louisiana. However since the installation of the levees, Louisiana's coastal wetlands have been deprived of practically all the sediment (about 220 million tons annually) that the river is transporting to the Gulf of Mexico (GOM). Therefore, alternative solutions to recover or re-direct portion of this massive amount of valuable sediment to benefit Louisiana's coast are currently being considered. In order for such effort to be successful, the impact of restoration projects on the River (supply side) and on the surrounding wetland and water bodies (demand side) should be considered.

The project reported herein focuses on the supply side, namely, the MR itself. Thus, it is the project goal to develop a detailed and accurate numerical model for the portion of the Lower MR from Tarbert Landing to Venice. The development of such a tool is a complicated and laborious task. It is being accomplished by using a combination of models with different spatial dimensions, i.e., 1-, 2- and 3-D; different methodologies, i.e., finite difference and finite element; and different grid resolutions. After completion, the model will provide detailed information on the spatial and temporal patterns of the river's hydrodynamics, salinity, sediment and water quality parameters.

The calibration and validation of the 2-D, and 3-D models are underway. Such results will be presented in the poster at the conference. This paper focuses on: 1) model selection, 2) 1-D model setup and calibration, and 3) grid generation for 2- and 3-D models.

BACKGROUND

Earlier modeling efforts have been devoted for the MR. The United States Corps of Engineers' (USACOE) Engineer Research and Development Center (ERDC) developed a computer model, using the TABS-MD modeling system, for portion of the Lower MR that includes the Head of Passes, and approximately 10 miles of the main channel. Researchers at ERDC also used the CH3D-SED numerical modeling system to evaluate dredging, channel evolution, and channel training issues in the Lower MR. Spasojevic and Holly (1994) incorporated a 2-D mobile bed technique into the USACOE CH3D model to simulate the flow and sediment transport at the Old River Structure. The 1-D hydrodynamic and sediment transport model HEC-6 has also been applied to the Lower MR to determine the sensitivity of dredging requirements to flow and relative sediment diversions (Barbe et al. 2000). At the moment of writing this abstract, and to the best of the research team's knowledge, there is no previous research effort to model large scale portion of the Lower MR, namely from Tarbert Landing to Venice using a multi-dimension model.

A review of various publications concerned with the river hydrologic characteristic (e.g., Wells 1980) and several river-modeling applications (e.g., Demuren 1993, Meselhe et al. 2000, Corti and Pennati 2000) indicated that complex flow patterns of three-dimensional nature characterize the hydrodynamics of the Lower MR. Therefore a 3-D model is needed to provide information on the river's secondary motion, the sediment distribution of the water column and the modeling of the salt water wedge. One- and two-dimensional models can be used as auxiliary models for routing water and sediments.

MODEL SELECTION

Four numerical modeling systems with different methodologies were considered for the selection process, namely TELEMAC, H3D, ADCIRC, and ECOMSED. The evaluation criteria consisted of computational efficiency/ability to run in parallel mode, accuracy, robustness, general capabilities, and a comparison of three-dimensional setup versus a depth-averaged setup. The accuracy of the models were evaluated by comparing the following criteria to measured data: (A) water surface slope, (B) flow splits around islands, (C) vertical velocity profiles, (D) statistical analyses of two-dimensional planes, (E) secondary motion, and (F) CPU simulation time. The Detroit River, which is located on the southeastern border of the state of Michigan, was identified as a suitable test case. This river was selected because of the abundance of bathymetry and field data readily available. Based on the results from this test case, two models were selected for the MR: (1) H3D due to its accuracy and computational efficiency, and (2) TELEMAC due to its accuracy and flexibility to capture complex geometries.

MISSISSIPPI RIVER MODELING EFFORT

ONE-DIMENSIONAL MODEL SETUP AND CALIBRATION

The research team set up a 1-D model for the MR from Tarbert Landing to Venice. This 1-D model was developed using the Danish Hydraulic Institute's product MIKE 11, and will be used along with TELEMAC-2D for routing water and sediment from Tarbert Landing to Bonnet Carre, and to other river locations as needed. Two different set of boundary conditions were tested for the model calibration: 1) firstly, the 1-D model was driven using discharge data at the upstream boundary condition (at Tarbert Landing), and water levels at the downstream end (Venice); 2) secondly, a stage boundary was imposed at Tarbert Landing instead of discharge. The entire year of 2003 was selected as calibration period. The bed roughness was the main calibration parameter. It should be noted that the bed roughness was spatially variable, and was allowed to change with respect to flow depth.

Figure 1 shows the comparison between observed and simulated stages for the 1-D model using discharge data at the upstream boundary condition and water level at the downstream end. With this initial setup, some discrepancies were observed between the model prediction and the field measurements. The differences observed in Figure 1 may be due to the inability of the 1-D model to represent actual flow's dynamics in the river, or it could be due to inaccuracy of the rating curve used at Tarbert Landing to estimate the flow discharge. Accordingly, using water level boundary condition at both ends of the model domain was tested as shown in Figure 2. The calibration results using this setup indicate that the model performance to match overall stage hydrographs improved considerably. Comparisons between observed and predicted water levels and discharges for this set of boundary conditions are presented in Tables 1 and 2. Table 1 shows the model performance in predicting water levels at different locations, and Table 2 shows the comparison between observed and predicted discharges at Tarbert Landing. The results presented in these Tables indicate that the 1-D model may be a useful tool for routing water for downstream locations as desired.

SETUP OF THE TWO- AND THREE-DIMENSIONAL MODELS

Two finite element grids of the Lower MR reach from Tarbert Landing to Bonnet Carre were created for the TELEMAC-2D modeling system using the MATISSE generator module. The first grid consists of 56,644 grid nodes and 109,918 elements, while the second grid is coarser and consists of 16,634 grid nodes and 31,359 nodes. Figure 3 shows the plan view and a 3-D view portion for the finer grid. This model is also intended to route water and sediment from Tarbert Landing to other downstream locations. In other words it would provide upstream boundary conditions for a 3D high resolution model. It is essential to model the lower reach of the Mississippi River in three dimensions in order to provide detailed information of sediment availability over the water column especially near diversion locations and to capture the flow stratification experienced in that reach.

For the H3D model, a curvilinear orthogonal grid from Bonnet Carre to the Venice consists of 685 (streamwise) x 20 (cross-stream) grid points. This grid was generated using the Tecplot's Mesh Generator 1.2 Module.

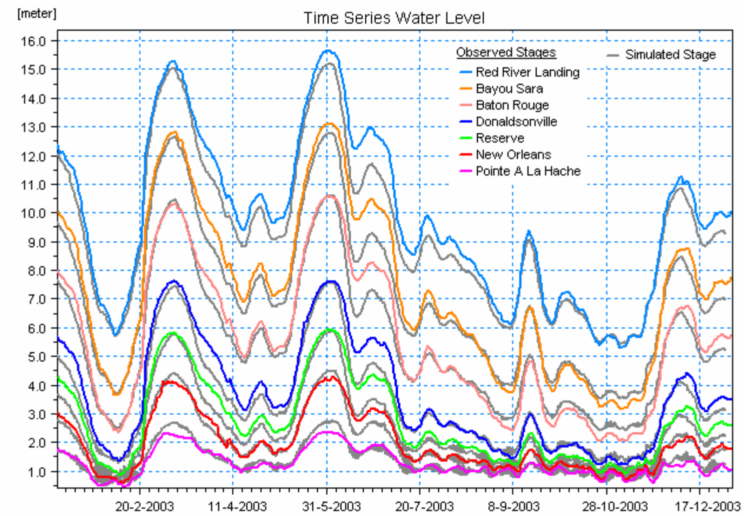

Figure 1. Observed and simulated stages at different locations with discharge at Tarbert Landing as upstream boundary condition.

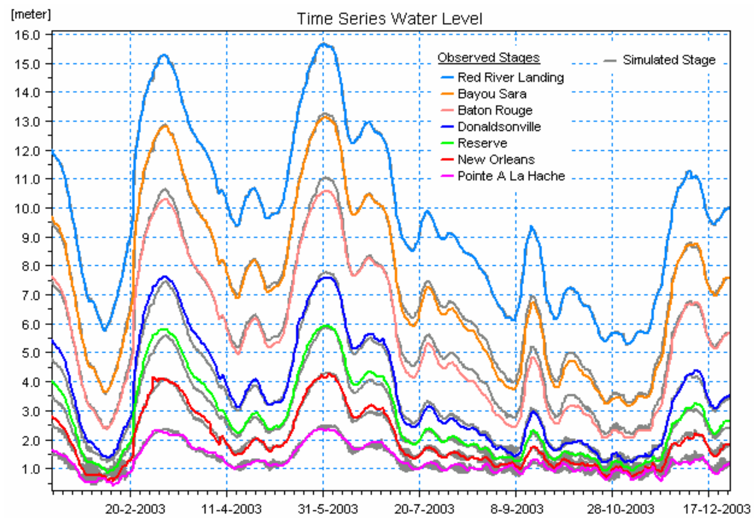

Figure 2. Observed and simulated stages at different locations with water level at Tarbert Landing as upstream boundary condition.

Table 1. Model performance in predicting water levels

Location	RMSE For Stage Hydrograph (m)	Coefficient of Efficiency, E	Peak Error (%)
Red River Landing	0.02	1.00	0.09
Bayou Sara	0.17	0.99	1.78
Baton Rouge	0.24	0.99	3.98
Mississippi at Donaldsonville	0.19	0.99	3.48
Mississippi at Reserve	0.18	0.98	3.68
New Orleans	0.11	0.98	3.46
Pointe A LA Hache	0.06	0.98	2.61

	Average	2.73

Table 2. Model performance in predicting discharge at Tarbert Landing

Observed Average Daily Discharge (m^3/s)	Simulated Average Daily Discharge (m^3/s)	RMSE (m^3/s)	RMSE (%)	Efficiency (%)	Peak Error (%)
13820	14939	1380	9.98	0.95	7.02

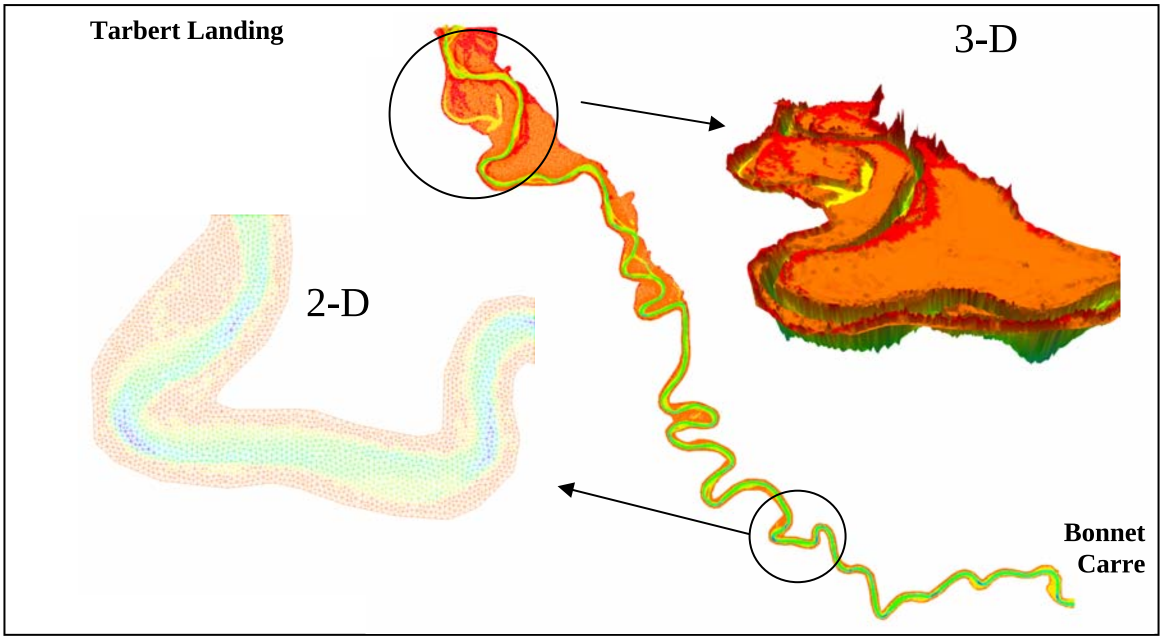

Figure 3. Mississippi River unstructured grid from Tarbert Landing to Bonnet Carre

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